The Design and Installation of an Automatic Liquid Nitrogen Fill System for Low Volume Dewars Used in the LLNL Whole Body Counting Facility.

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For several years the LLNL Whole Body Counting (WBC) Low Energy Germanium (LEGe) lung counting system had been plagued with intermittent warm-ups with no observable warning signs. This presentation will describe the process undertaken to correct this condition.

Refer to figure 1 for the following system description. (Note: this description pertains to the system before any modifications were addressed.)

Liquid Nitrogen (LN) for the WBC detectors is stored in a 3600 gallon bulk dewar 120 feet southwest of the building. LN from the bulk dewar is supplied via a vacuum insulated transfer line to a control hut located on the outside wall of the facility. The hut houses the insulated transfer line vacuum system and solenoid activated safety valves to terminate LN flow in emergencies. The vacuum insulated transfer line continues another 80 feet downstairs to the counting room, where it delivers LN to the LEGe solid state detectors via two distribution manifolds. Two copper vent lines, originating in the downstairs counting room, remove Nitrogen vent gas upon filling of the detectors and parallel the transfer line route out of the building.

During the first troubleshooting stages, changes were made to the frequency and duration of the fills. Although this did reduce the frequency of the warm-ups it did not solve the problem completely.

Next, viewing windows (see figure 2) were made to allow observation of the actual LN flow. These windows were inserted in the fill and vent hoses leading to and from the detectors. Using these windows it was determined that the LN flow through the distribution manifolds was not uniform. Also, the existing distribution manifold had suffered solenoid failures during this same period. For these reasons it was decided to design a new distribution manifold system.

During the redesign stage, it was deemed necessary to add a liquid level sensing diagnostic to the system. The first choice would have been direct liquid level sensing. However the dewar/detector design did not lend itself to this application. This required finding an alternate method to monitor the LN transfer. Thermocouples mounted in copper blocks, see figure 3, were used to monitor the LN in the vent lines of the detectors. Using the windows for direct observation, it was found that the thermocouples were successful at sensing the difference between two phase gas liquid and Liquid Nitrogen. It was decided to use the temperature feedback in conjunction with time to control the LN transfer process.

A new distribution manifold was designed to allow discrete filling of each detector while using thermocouple feedback to control fill time. A Programmable Logic Controller (PLC) was selected for both control and monitoring functions. Selection of a PLC also added the ability to perform trend analysis.

A mock-up of the new fill system, see figure 4, using as many of the actual components as possible was built and the PLC programmed to control the process. The designers include the following fault scenarios in the program design to produce a fault tolerant process:

- Valve failures (electrical and mechanical)
- Temperature sensor failures (open thermocouple, out of tolerance reading)
- Impeded flow (ice blockages, ruptured lines, and variations in LN flow and pressure)
- Power interruptions

To include the above scenarios, tables in the PLC program contain minimum and maximum cool down parameters, detector fill times, and calibrated values for each thermocouple. The calibration values for each thermocouple are compared with the LN sensed values. This comparison is used to verify thermocouple stability during each fill cycle. In addition, the PLC monitors it's power sources and enables an alarm should a power failure occur.

The new system functions as follows:

The main LN supply solenoid is opened allowing LN to pre-cool the manifold for the minimum period of time. The temperature of the manifold is then monitored for the presence of LN. Should the temperature indicate LN is not yet present, the PLC will continue to supply LN for the maximum time allowed or until LN is sensed in the vent line. The manifold vent solenoid then closes and each detector is sequentially filled using the above time and temperature sense process. After the fill cycle is complete the LN supply solenoid is closed and the manifold vent solenoid is opened. The vent line temperature is monitored to insure that LN flow has stopped.

The following conditions in the above process will cause an alarm to be issued giving early warning of a pending problem:

- The maximum programmed time is reached in any step
- An open thermocouple is detected at anytime
- LN is sensed after the fill process is complete
- Power to the solenoids or the system is lost.

The alarm condition triggers an auto dialer which will page four members of the WBC team notifying them of an alarm condition.

The following condition in the above process will cause a warning condition to be issued:

- The LN sensed and calibrated values disagree

This warning does not trigger an alarm, but does notify the operator that the system is in need of calibration or maintenance by lighting an LED.

Additional features have been included to simplify operation of the system.

- It is now possible using the LN manifold control panel to fill or skip any or all detectors as needed, allowing maintenance to be performed on various detectors without disrupting the fill process of the remaining detectors.
- A hold feature has been installed to allow the operator to delay an automatic fill until a count is complete. The system can then be returned to the run condition at which time the fill will start automatically.
- A minimum cool down time override was added for multiple fills of a warm detector when the LN transfer line is already cold.

The new system has been in operation for several months, giving time to analyze the data. It has been observed that the actual cool down time varies widely with time of day and outside temperature. At this time, it is believed that the reason for the intermittent warm-ups were due to large differences in cool down times of the supply line with respect to outside ambient temperature. However, the new sensed fill system has compensated for the variations in cool down time and has insured complete fills of each detector, eliminating the intermittent warm-ups.

Conclusion:

In going to a dynamically controlled LN delivery system the following has been achieved:

- Compensated for many external variables which can have negative effects on LN transfer over long distances where the environment cannot be controlled.
- Provided warning of pending problems to allow response and correction of problems before a warm-up occurs.

Also, the flexibility of operation has allowed the operators to perform tasks that would have previously been maintenance

ORIGINAL LEGe LN TRANSFER SYSTEM

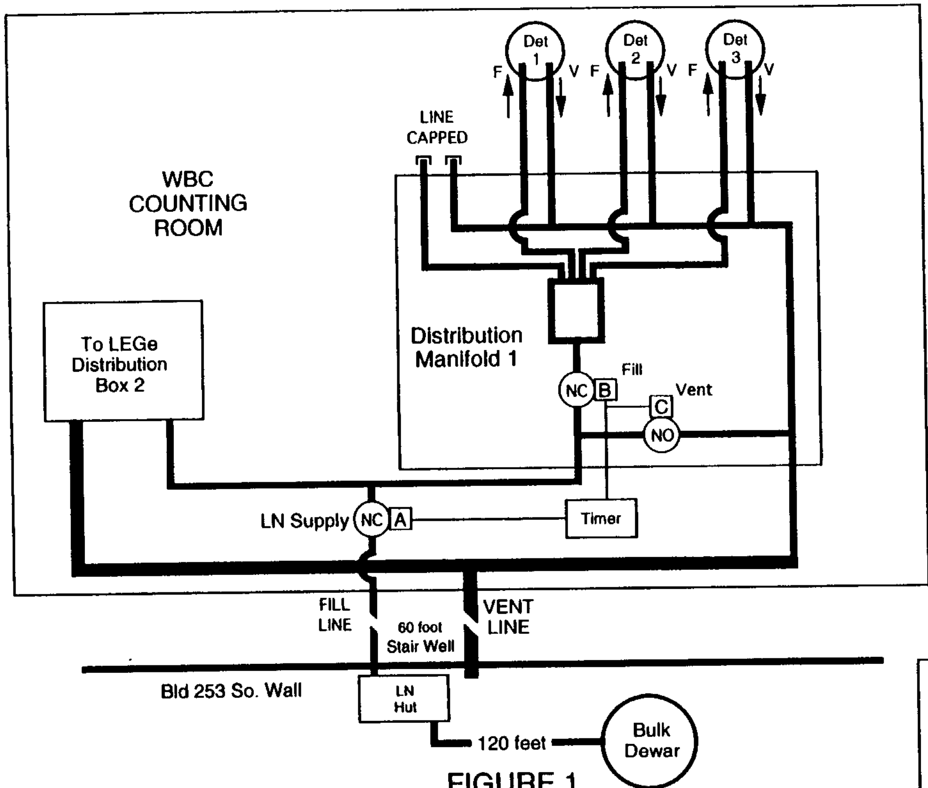

FIGURE 1

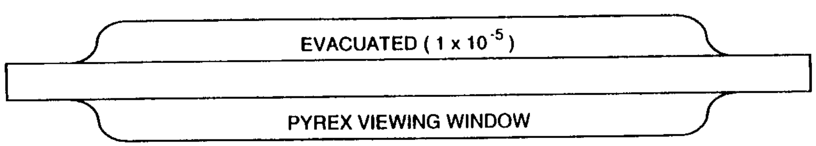

FIGURE 2

THERMOCOUPLE SENSOR AND BLOCK

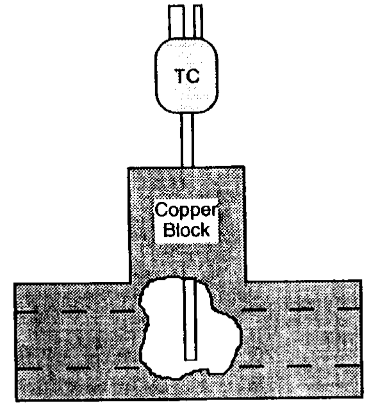

FIGURE 3

NEW LEGe LN TRANSFER SYSTEM

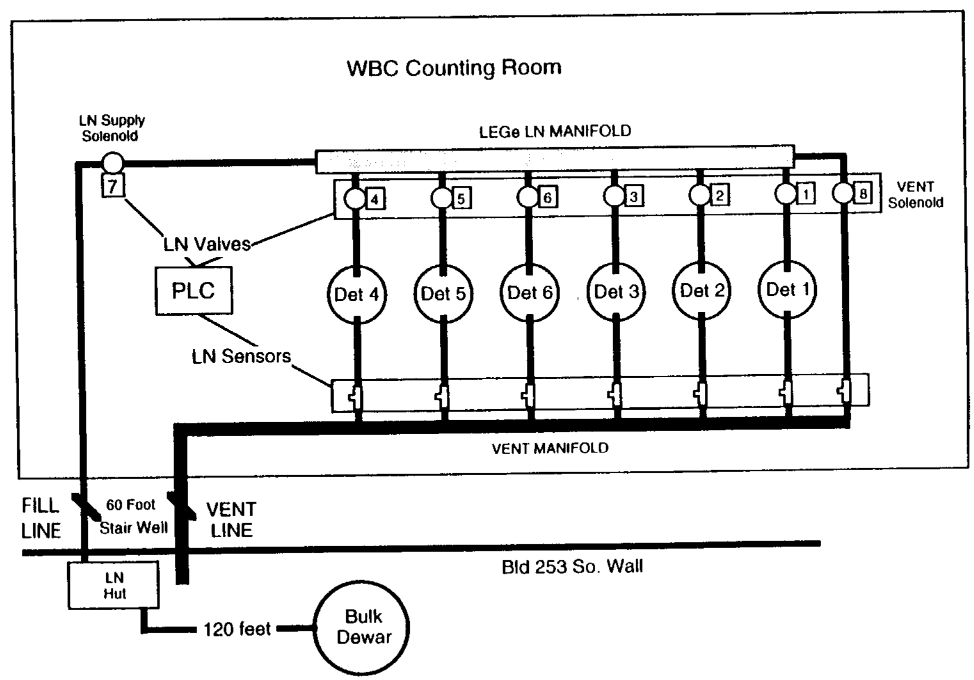

FIGURE 4